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RISK ASSESSMENT WORK PLAN

Prepared for:

CEDAR CHEMICAL CORPORATION
WEST HELENA, ARKANSAS

Prepared by:

Environmental Safety and Designs, Inc.
5724 Summer Trees Drive
Memphis, Tennessee 38134
(901) 372-7962

July 1, 1996

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1.0 INTRODUCTION

Cedar Chemical Corporation agreed to conduct a Facility Investigation (FI) pursuant to the Consent Administrative Order (CAO) No. LIS 91-118, issued by the Arkansas Department of Pollution Control and Ecology (ADPC&E) for the Cedar Chemical facility in West Helena, Arkansas. Fieldwork for Phase I of the FI began on August 30, 1993. Upon completion of Phase I, a Technical Memorandum submitted to ADPC&E summarized the investigation's findings. Based on the results of the field sampling and analysis, Phase II of the FI was recommended to fill data gaps and further delineate contamination identified in the first phase. Following ADPC&E's approval of the submitted work plan, Phase II began on November 7, 1994. Upon completion of Phase II, a Facility Investigation Report was submitted to ADPC&E for review and comment. Per ADPC&E comments, in order to finalize the FI report, Cedar Chemical was required to characterize and delineate the source of 1,2-dichloroethane in soil, and delineate the vertical and areal extent of 1,2-dichloroethane in groundwater. The Interim Response Work Plan (Phase III), addressing these issues, was submitted for approval on April 10, 1995. Field work for Phase III began on September 19, 1995. The July 1, 1996 report documents Phases I, II and III of the FI (EnSafe, 1996).

Cedar Chemical Corporation owns and operates the subject chemical manufacturing facility in Phillips County, Arkansas, just south of West Helena, Arkansas. The site consists of approximately 48 acres along State Highway 242, one mile southwest of the intersection of U.S. Highway 49 and Highway 242. A map of the area surrounding the facility is included in Figure 2-1 of the July 1, 1996 FI, while Figure 2-2 shows the facility site plan.

The facility consists of five production units and support facilities, an office on the north side of Industrial Park Road, and a biological treatment system (i.e., 2 ponds) south of the road. The entire Cedar facility is fenced to control access. Active processes are conducted on

approximately 20 acres. The rest of the site contains the biological treatment ponds and closed surface impoundments, or is unoccupied.

Cedar Chemical manufactures various agricultural chemicals and organics including insecticides, herbicides, polymers, and organic intermediates. Plant processes are batch operations with seasonal production fluctuations and frequent product introductions. Cedar Chemical manufactures its own products (such as Propanil, a rice herbicide) and also custom manufactures chemicals for contract clients. Formulation and packaging are ancillary activities, and are conducted only when the product is ready for the consumer market.

A Baseline Risk Assessment (BRA) analyzes the potential adverse effects on actual or hypothetical human and ecological receptors that could arise from exposures to hazardous substances released from a site if no remedial actions are taken to reduce the extent of present environmental contamination. Generally, a BRA is divided into two subsections — one addresses human health risk, and the second assesses ecological risk. Ecological concerns are not discussed in this work plan, which was written to present methods to assess human health risk posed by chemicals reported on and around the Cedar Chemical Facility, West Helena, Arkansas. The proposed risk assessment (RA) methods are discussed in the following text.

2.0 HUMAN HEALTH RISK ASSESSMENT APPROACH

2.1 Introduction

Sections 2.1.1 through 2.1.8 provide a general risk assessment approach, including general methods, procedures, considerations, the background for toxicological information used in risk assessment, and general related uncertainties possibly affecting risk estimated in accordance with this work plan.

The RA will be prepared generally in accordance with the guidelines set forth in:

- *Risk Assessment Guidance for Superfund (RAGS), Volume I — Human Health Evaluation Manual (Part A)*, (USEPA, 1989a) (RAGS Part A).

- *RAGS, Volume I — Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals)*, (USEPA, 1991a) (RAGS Part B).

- *RAGS, Volume I — Human Health Evaluation Manual, Supplemental Guidance — Standard Default Exposure Factors — Interim Final,* (USEPA, 1991b) (RAGS Supplement).

- *RAGS, Volume I — Human Health Evaluation Manual, Supplemental Guidance - Dermal Risk Assessment — Interim Guidance*, (USEPA, 1992d) (Supplemental Dermal Guidance).

- Supplemental Guidance to RAGS: Region IV Bulletin, *Risk Assessment - Interim* (USEPA Region IV, 1995a).

- Supplemental Guidance to RAGS: Region IV Bulletin, *Development of Health-Based Preliminary Remediation Goals, Remedial Goal Options (RGO) and Remediation Levels* (USEPA Region IV, 1994) (Supplemental RGO Guidance).

- Supplemental Guidance to RAGS: Region IV Bulletin, *Provisional Guidance of Quantitative Risk Assessment of PAHs,* (USEPA Region IV, 1993) (PAH Guidance).

- *Exposure Factors Handbook* (USEPA, 1989d).

- USEPA Region III *Risk-Based Concentration Table, January-June 1996,* (USEPA Region III, October 1995) (RBC Screening Tables).

- *Technical Memorandum Guidance on Estimating Exposure to VOCs During Showering* (USEPA, 1991c).

References are identified fully in Section 3, References.

2.2 Objectives

The objectives of the RA are to:

- Characterize the source media and determine the chemicals of potential concern (COPCs) for affected environmental media

- Identify potential receptors and quantify potential exposures for those receptors under current and future conditions for all affected environmental media

- Qualitatively and quantitatively evaluate the adverse effects associated with the site-specific COPCs in each medium

- Characterize the potential baseline carcinogenic risk and noncarcinogenic hazards associated with exposure to impacted environmental media under current and future conditions

- Evaluate the uncertainties related to exposure predictions, toxicological data, and resultant carcinogenic risk and noncarcinogenic hazard predictions

- Establish RGOs for chemicals of concern (COCs) in each environmental medium based on risk/hazard to facilitate risk management decision-making

Chemical contamination at the site must be characterized adequately before risk assessment can determine whether detected concentrations have the potential for toxic effects or increased cancer incidences and before it can serve as a basis for making remedial decisions. Variables considered in characterizing the study area are the amount, type, and location of contaminant sources. Variables considered for risk characterization are the pathways of exposure (media type and migration routes); the type, sensitivities, exposure duration, and dynamics of the exposed populations (receptors); and the toxicological properties of identified contaminants.

The focus of the FI is the past and present use of the site, now operated by Cedar Chemical. The FI currently ongoing at Cedar Chemical will be the source of data to be used in the RA. Tables will be used to present the sample identification numbers and analytical methods applied for each sample used in the RA. Analytical results from the samples shown in the FI tables and sample data collected to supplement the FI will be used to assess possible exposure to environmental contaminants.

Organization

A risk assessment, as defined by RAGS Part A, includes the following steps:

- *Site characterization*: Evaluation of data regarding site geography, geology, hydrogeology, climate, and demographics.

- *Data collection*: Analysis of environmental media samples, including background/ reference samples.

- *Data evaluation*: Statistical analysis of analytical data to identify the nature and extent of contamination and to establish a preliminary list of COPCs based on risk-based and background screening. This list will subsequently be refined to identify COCs.

- *Exposure assessment*: Identification of potential receptors under current and predicted conditions and potential exposure pathways, and calculation/quantitation of exposure point concentrations (EPCs) and chemical intakes.

- *Toxicity assessment*: Qualitative evaluation of the adverse effects of the COPCs, and quantitative estimation of the relationship between exposure and severity or probability of effect.

- *Risk characterization*: A combination of the outputs of the exposure assessment and the toxicity assessment to quantify the total noncancer and cancer risk to the hypothetical receptors.

- *Uncertainty*: Discussion and evaluation of the areas of recognized uncertainty in risk assessments in addition to medium- and exposure pathway-specific influences.

- *Risk/Hazard Summary*: Presentation and discussion of the results of the quantification of exposure (risk and hazard) for the potential receptors and their exposure pathways identified under the current and future conditions.

- *Remedial Goal Options*: Computation of exposure concentrations corresponding to risk projections within the USEPA target risk range of 10^{-6} to 10^{-4} for carcinogenic COCs and Hazard Quotient (HQ) goals of 0.1, 1, and 3 for noncarcinogenic COCs.

This general process will be followed in preparing the RA for Cedar Chemical.

2.3 Site Characterization

When performing a RA, environmental media data are compiled to determine potential site-related chemicals and exposures for each medium as outlined in RAGS Part A. The steps which will be used to identify COPCs are discussed below.

2.3.1 Data Sources

As part of the FI, soil, groundwater, and sediment samples were collected and analyzed to delineate the sources, nature, magnitude, and extent of any contamination associated with current or past site operations. Surface water data will be collected during later sampling activities. The data to be used in the RA were obtained from the results of the FI and associated sampling activities.

2.3.2 Data Validation

Data validation is an after-the-fact, independent, systematic process of evaluating data and comparing them to established criteria to confirm that they are of the technical quality necessary to support the FI decisions. Parameters specific to the data are reviewed to determine whether they meet the stipulated DQOs. The quality objectives address five principal parameters: precision, accuracy, completeness, comparability, and representativeness. To verify that these objectives are met, field measurements, sampling and handling procedures, laboratory analysis and reporting, and nonconformances and discrepancies in the data are examined to determine

compliance with appropriate and applicable procedures. Data for Cedar Chemical were validated as discussed in Volume II of the FI. In its validated form, the dataset will be deemed usable for assessing risk.

2.3.3 Management of Site-Related Data

All environmental sampling data will be evaluated for suitability for use in the quantitative RA. In accordance with RAGS, data obtained via the following methods are not appropriate for the quantitative RA:

- Analytical methods that are not specific for a particular chemical, such as TOC or total organic halogen.

- Field screening instruments including total organic vapor monitoring units and organic vapor analyzers.

Because duplicate samples were collected for QA/QC, more than one analytical result exists for some sample locations. One objective of data management is to provide one result per sample location per analyte. The mean of duplicate sample results will used as the applicable value, unless an analyte is detected in only one duplicate sample. In such cases, the detection results will be used.

In addition, the RA will address limitations of analytical results by including estimated concentrations for nondetected parameters. A nondetect indicates that the analyte was not detected above the quantitation limit of the sample (*U*-qualified results), which is determined by the analytical method, the instrument used, and possible matrix interferences. However, a nondetected analyte could be present at any concentration between zero and the quantitation limit. For this reason, one-half the *U* value could serve as an unbiased estimate of the nondetect. Because the estimated values are frequently much lower than the sample quantitation limits of *U*-qualified nondetects for organic compounds, one-half of each *U* value will be compared to one-half of the lowest hit (normally *J*-qualified). The lesser of these two values

will be used as the best estimate of the concentration that was potentially present below the sample quantitation limit, and will be inserted into the adjusted dataset.

For inorganic chemicals, the decision rule is less complex: one-half of each *U* value will represent the concentration of the corresponding sample when compiling the adjusted dataset. If two nondetects were reported for any one location (a result of QA/QC samples), one-half the lesser of the *U* values will be compared to the lowest hit at the site or distinct geographic area of the site (for organics, as above) or applied directly (for inorganics) to estimate a concentration value to be used in the risk calculations. If a parameter is not detected at the site, neither data management method will be applied, and the parameter will not be included in screening or formal assessment.

Once the dataset is complete (i.e., after elimination of faulty data, consolidation of duplicate data values, and quantification of censored values), statistical methods will be used to evaluate the FI analytical results to: (1) identify COPCs and (2) establish EPCs at potential receptor locations. The statistical methods typically used in data evaluation are discussed below, and others may be used as appropriate. The rationale used to develop this methodology and the statistical techniques to implement it are based on the following sources:

- RAGS Part A
- *Statistical Methods for Environmental Pollution Monitoring* (Gilbert, 1987)
- *Supplemental Guidance to RAGS: Calculating the Concentration Term* (USEPA, 1992)
- *Others (as appropriate)*

Microsoft FoxPro and Borland Quattro Pro[1] will be used to manage data and calculate statistics. For each set of data describing the concentration of chemicals in a contaminated area, the following information will be tabulated: frequency of detection, range of detected values,

[1] Reference to specific software products are not to be constructed as a endorsement by the U.S. Navy or E/A&H.

average of detected concentrations, and the calculated 95th percentile upper confidence limit (UCL) on the mean of log transformed values of the concentration. The range of reported concentrations, area affected, arithmetic mean, and UCL will be used to quantify exposure. The EPC will be determined on a site-specific basis, which will be described in the RA. This procedure is detailed in Section 2.3.6 of this document.

2.3.4 Selection of Chemicals of Potential Concern

The objective of this section of the RA is to screen the available information on the substances detected at the site to develop a list or group of COPCs. COPCs are chemicals selected by comparison with screening concentrations (risk-based and reference), intrinsic toxicological properties, persistence, general fate and transport characteristics, and cross-media transport potential. Risk and hazard will be estimated for COPCs to determine if assessment relative to corrective measures is necessary.

COCs will then be identified from the COPCs based on risk estimates. For any COPC to be considered a COC, it must meet two criteria. First, the COPC must contribute to an exposure pathway with an incremental lifetime excess cancer risk (ILCR) in excess of 10^{-4} or hazard index (HI) greater than 1 for any of the exposure scenarios evaluated in the risk assessment. Secondly, the COPC must have an individual risk estimate greater than 10^{-6} or an HQ greater than 0.1. ILCR, HQ, and HI are detailed in Sections 2.3.7 and 2.3.8 of this report.

Before evaluating the potential risks/hazards associated with site media, it is first necessary to delineate the contamination onsite. Section 7 of the FI Report discusses the nature and extent of contamination at Cedar Chemical. In the RA, the nature and extent of contamination will first be considered by noting the chemicals detected in environmental media. These chemicals will represent the CPSSs at the site. Because human health risk and hazard could ultimately direct remedial action, detailed discussions of COC extent will be summarized in the RA as necessary. Where data support such depictions, the Risk Characterization section of the RA will provide risk and hazard maps for COCs as visual aids in interpreting the risk estimates. Where data do

not support development of relevant visual presentations, affected locations will be discussed for each medium.

To reduce the list of CPSSs and thereby focus the risk assessment on COPCs, two comparisons will be performed as described below.

2.3.4.1 Comparison of Site-Related Data to Risk-Based Screening Concentrations

The maximum concentrations of CPSSs detected in samples will be compared to risk-based screening values. These values will be obtained from *Risk-Based Concentrations, USEPA Region III,* January through June, 1996 (or subsequent versions). As stated in the USEPA Region III document, a risk goal of 10^{-6} was used by USEPA to calculate screening concentrations for carcinogens. Noncarcinogenic chemical values will be adjusted from an HQ of 1.0 to an HQ of 0.1, which is more conservative than using screening values directly from USEPA's document (USEPA, 1996).

Groundwater and surface water data will be compared to industrial tap water screening values and maximum contaminant levels (MCLs). USEPA's document does not provide industrial tap water values, but USEPA provided a method to convert residential-based tap water RBCs to industrial-based RBCs. RBCs will be converted and presented in tabular form in accordance with RAGS (USEPA 1994c, USEPA 1995b). Chemicals reported in groundwater will be excluded from the RA if the reported concentrations are less than either of the RBCs or MCLs. The lead groundwater screening value to be used is the USEPA Office of Water treatment technique Action Level of 15 μg/L.

Reported soil and sediment concentrations will be compared to industrial soil ingestion screening values. VOC concentrations will be compared to the soil-to-air RBCs to identify COPCs for the inhalation and fugitive dust scenarios. In addition, sub-surface soil data will be compared to RBCs calculated by USEPA to be protective of groundwater. A synopsis of the potential for contaminants in soil to migrate via groundwater will be evaluated using these screening comparisons made using groundwater protection RBCs. The soil screening value for lead will

be 1300 mg/kg, consistent with recent OSWER directives considering protection of an industrial site (USEPA 1994b).

Carcinogenic polycyclic aromatic hydrocarbons (cPAHs) have not been identified as site contaminants in the FI. The method which will be used to assess the associated risk is described below for chemicals identified as a concern during upcoming quarterly monitoring or any supplemental sampling activities. Where appropriate, benzo(a)pyrene equivalents (BEQs) will be computed in accordance with recent cPAH guidance (USEPA, 1993). BEQ is calculated by multiplying the reported concentration of each cPAH by its corresponding TEF. The BEQ values are then summed for each sample, and the total is compared to the benzo(a)pyrene RBC value during the screening process. Subsequent exposure quantification and risk/hazard projections for cPAHs in soil and groundwater will be performed using total BEQ values for each sampling location rather than for individual compound concentrations.

A CPSS will be retained for further evaluation and reference screening in the risk assessment, if its maximum detected concentration exceed corresponding screening values. Screening values based on surrogate compounds will be used if no screening values are available in USEPA's table. Any surrogate compounds used will be so noted in the RA. Surrogate compounds will be selected based on structural, chemical, or toxicological similarities.

The relevance of groundwater RBC screening is discussed in Sections 2.3.6 and 2.3.8. Because groundwater beneath Cedar Chemical may contain chlorides and/or total dissolved solids (TDS) above Arkansas potable source criteria, water from these aquifers may not be appropriate for domestic well use. Consequently, screening the concentrations of compounds detected in groundwater against tap water RBCs provides a highly conservative assessment of the significance of groundwater impacts.

2.3.4.2 Comparison of Site-Related Data to Background Concentrations

Soil background concentrations were determined for inorganics in the FI, using results from three background sampling locations. Surface soil, subsurface soil, and groundwater were all

addressed separately as discussed in Section 7 of the FI, Nature and Extent of Contamination, which includes the method used to determine the background concentrations to be applied in the RA.

After risk-based screening values (Section 2.3.4.1) are compared to concentrations reported onsite, COPC concentrations will be compared to any available background or reference data. COPCs will be retained for further consideration as COCs in the RA, if their maximum detected concentrations exceed corresponding background reference concentrations. By virtue of this process, risk and/or hazard associated with naturally occurring chemicals is not addressed where their concentrations are not above corresponding background.

In the RA, the CPSS will not be considered further in the risk assessment if its maximum concentration is determined to be less than either background or the risk-based screening value, unless deemed appropriate based on chemical-specific characteristics (e.g., degradation product with greater toxicity).

2.3.4.3 Elimination of Essential Elements: Calcium, Iron, Magnesium, Potassium, and Sodium

In accordance with RAGS Part A, essential elements that are potentially toxic only at extremely high concentrations may be eliminated from further consideration as COPCs in a risk assessment. Specifically, an essential nutrient may be screened out of a risk assessment if it is present at concentrations not associated with adverse health effects. Based on RAGS and the lack of risk-related data, the following essential nutrients will be eliminated from the risk assessment: calcium, iron, magnesium, potassium, and sodium.

2.3.4.4 Summary of COPCs

In summary, data collected from each environmental medium will be screened using both risk-based and background values. The results of the screening process will be presented in tabular format in each RA. Chemicals determined to be COPCs through the screening process will be designated as such on the tables.

2.3.5 Calculation of Risk and Hazard

As previously discussed, a CPSS that exceeds its respective screening value will be considered a COPC. The subsequent identification of COCs is a two-phase process. First, exposure pathways exceeding the screening criteria established by USEPA are identified. Identifying COCs from the refined list of COPCs involves estimating reasonable maximal exposure (RME) and central tendency (CT) exposure, calculating chemical-specific cancer risks and HQs for COPCs, estimating exposure-pathway risk/hazard, evaluating frequency and consistency of detection and relative chemical toxicity, and comparing them to background concentrations. In the next step, COPCs which individually exceed 10^{-6} ILCR or an HQ greater than 0.1 in a pathway of concern (i.e., an exposure pathway having ILCR greater than 10^{-4} or HI greater than 1) are retained as COCs. When estimating cumulative risk, the toxicology of COPCs will be considered and discussed to logically group chemicals according to toxic effects, target organs, and mechanisms of action. Section 2.3.7 discusses cancer risk thresholds and noncancer toxicity.

2.3.6 Exposure Assessment

The magnitude of contact that a potential receptor may have with site-related COPCs will be determined in this section of the RA. Exposure assessment involves several stages:

- Characterizing the physical setting and land use of the site
- Identifying COPC release and migration pathway(s)
- Identifying the potential receptors, under various land use or site condition scenarios, and the pathways through which they might be exposed
- Quantifying the intake rates, or contact rates, of COPCs

2.3.6.1 Exposure Setting and Land Use

This section will describe the basic layout of the site as well as the suspected sources of contamination. Currently, there are nine sites at the facility, and grouping sites and their associated data may be warranted based on the exposure setting and chemicals detected. Rationale for any grouping will be discussed as appropriate in the RA.

Existing site features such as asphalt surfaces, buildings, and fences would prevent and/or minimize exposure to impacted media if these features are maintained. The potential influences of existing site features on exposure will be evaluated. Where current site features affect how an individual might be exposed, they will be analyzed to more accurately reflect the probability of contact and to derive factors to account for fraction ingested/contacted (FI/FC) from the contaminated source.

The site is in the Helena-West Helena Industrial Park, and current land use is industrial. Cedar Chemical is bounded by Arkansas Highway 242 to the northwest, a Union-Pacific railway to the northeast, and other industrial park properties to the southeast and southwest. The land across Highway 242 is agricultural. Residential areas are within one-half mile southwest and northeast of the site. Several domestic wells and irrigation wells were within a one-mile radius of the site; however, all of the domestic wells identified in a door-to-door survey were no longer used. Grubbs, Garner & Hoskyn, Inc. (GG&H), of Little Rock, Arkansas, conducted a well survey in 1988. Plate 19 of the GG&H report (July 19, 1988) presents the locations of the irrigation wells in the West Helena vicinity. EnSafe's 1995 well survey is discussed in Section 2.4 of the FI.

Much of the nonhazardous process and sanitary wastewater discharges to a three-pond biologic treatment system on the west side of the plant across Industrial Park Road. Effluent from the treatment system is pumped offsite through a 4.5-mile pipeline which discharges directly into the Mississippi River through National Pollutant Discharge Elimination System (NPDES)

permitted outfall No. 002. Storm water runoff across the site is channeled through a series of ditches which drain to the southwest corner of the site, where it is pumped under industrial park road to the treatment ponds. No other waste is treated or disposed onsite.

The facility employs approximately 125 people. The plant operates 24 hours a day, seven days a week. Work is performed in shifts, and therefore, RBCs for industrial sites will be appropriately used as screening values.

Unit 1 formulates various custom agricultural products for other companies. Unit 2 is the Propanil production unit. Unit 3 was destroyed in a fire and explosion on September 26, 1989. Unit 4 produces various custom products. Unit 5 primarily manufactures nitroparaffin derivatives. In 1991, Unit 6 began producing dichloroaniline, which is used in the production of Propanil.

Cedar Chemical is a large-quantity generator of hazardous wastes. Most of these wastes are classified as hazardous through process knowledge; therefore, no data from analysis of the waste are available.

Although most of the hazardous waste generated at the facility is transported offsite for disposal, some basic treatment processes do occur onsite regarding characteristic wastes. Waste propionic acid and waste sodium hypochlorite scrubber liquor treated in enclosed treatment vessels within process units at the site are exempt from hazardous waste permitting. Waste propionic acid undergoes elementary neutralization through the addition of anhydrous ammonia. Waste sodium hypochlorite is treated with sodium sulfite to remove excess hypochlorite. After treatment, these materials, which no longer exhibit the corrosivity characteristic of a hazardous waste, are discharged to the biological treatment ponds.

The remaining hazardous wastes generated are shipped offsite for disposal. Cedar Chemical does not currently conduct onsite storage or disposal activities for the hazardous wastes generated there. Except for the wastes described in the previous paragraph, hazardous wastes generated at the facility are stored onsite less than 90 days and transported offsite for disposal at an approved landfill, incinerator, or deep-well injection facility. Any airborne constituents emitted from the plant are provided for under Permit 878-AR-9 issued on October 3, 1994, by the ADPC&E.

The plant filed a Part A hazardous waste management facility permit application with the ADPC&E in November 1980. Interim status was granted for a hazardous waste storage tank, a hazardous waste container storage area, and a hazardous waste treatment unit (the biological treatment system). A Part B application filed on August 15, 1984, was accepted through the notice of deficiency (NOD) process as technically complete. However, the two storage units were closed in accordance with Resource Conservation Recovery Act (RCRA) regulations in 1988. No post-closure care is required. Based on thorough review by ADPC&E, it was concluded that hazardous waste was not being treated at the biological treatment system. Therefore, ADPC&E never processed the Part B application.

Certain nonhazardous wastestreams, which are evaluated individually, are sent to offsite disposal facilities because of their incompatibility with the biological treatment system. An example of this is a wastestream with a high salt concentration.

Onsite waste disposal methods were used at the facility before Cedar Chemical acquired it. It is known that during certain periods between 1971 and 1973, the former owners began disposing of wastewaters in three unlined earthen ponds. Thereafter, Helena Chemical Company (at the time an affiliate of the site owner) used the ponds to dispose of wastewater generated in its formulating and packaging operations at a nearby Helena Chemical facility where agricultural chemicals were also produced.

During the previous period of onsite disposal, the three ponds are believed to have received propionic acid wastes, a calcium chloride brine stream from an insecticide process, and a sulfuric acid waste. The small pond was used to neutralize dichloroaniline, sulfuric acid, and propionic acid through limestone addition. The other two ponds were used for waste disposal. Wash waters from Helena Chemical's chemical formulation operations were also directed into the ponds. Helena Chemical formulated some 100 to 200 compounds, and has no knowledge of what types of wastes were disposed in the ponds. Helena Chemical stopped disposing of its wastes in the ponds in early 1976. The ponds were closed in 1978 by pumping the water from the ponds and placing a clay cap of native soil and bentonite over them. The water was removed and disposed by Rollins Environmental Services.

Before Cedar Chemical purchased the property, as many as 300 drums of waste were placed in a concrete vault beneath the onsite warehouse. The current condition and contents of these drums are unknown. The location of the vault and drums is shown in Figure 4-6, which is a slant boring schematic in Section 4 of the FI. While constructing a drainage ditch, buried drums were found near the newest production unit (Unit 6). Cedar Chemical has removed these buried drums in accordance with the approved removal work plan dated June 1990.

Since the current CAO was issued, Cedar Chemical officials obtained information from individuals who worked at the plant prior to Cedar's purchase concerning the existence and location of two additional drum burial sites. A geophysical survey was conducted at the site and subsurface anomalies were identified in the areas where drums were suspected to have been buried. Before 1991, removal actions were conducted by Cedar Chemical for the additional buried drums.

The Cedar Chemical facility is approximately two miles west of the Mississippi River in part of a physiographic province and setting known as the Mississippi Embayment Region of the Gulf Coastal Plain. The topography of the terrain at the site and surrounding area is relatively flat

with some areas dipping gently toward the southeast. Ground surface elevations at the site vary from about 188 feet mean sea level (msl) in the southwest to 200 feet msl in the northeast. Localized changes in topographic relief are due mainly to alterations for construction or for directing surface flow runoff. Generally, surface flow runoff tends to be toward the southeast and the Mississippi River. Since topography is relatively flat, overland flow velocities are low and some areas where the original ground surface has not been modified are poorly drained. To improve drainage, a series of unlined storm water drainage ditches has been constructed to divert runoff water to retention and treatment basins. The facility is not in the 100-year floodplain of the Mississippi River.

The lowermost geologic unit of concern at the site is the Sparta Sand of Tertiary age. The Sparta Sand consists mainly of a gray, very fine to medium sand with brown and gray sandy clay. This formation appears to consist of a beach complex deposited during a regressive phase of the ancient sea and ranges from 300 to 400 feet thick. The Sparta Sand serves as the major deep source of potable groundwater in the Helena/West Helena area. Regional groundwater flow in the Sparta Sand is generally southeast toward the Mississippi River.

Overlying the Sparta Sand is the undifferentiated Jackson-Claiborne Group, also deposited during the Tertiary. The Claiborne Group consists mainly of silty clay with some thin, discontinuous beds of silty clay and lignite. The Jackson Group typically comprises gray, brown, and green silty clay with some peat and lignite. In this area, the Jackson Clay is approximately 250 feet thick.

The Jackson Group is overlain by alluvial deposits of Quartenary Age. These deposits are approximately 150 feet thick and consist of coarse sands and fine gravels at the base of the unit, fining upward to fine sand, silt, and clay at the surface. Portions of these upper soils apparently consist of outwash from Crowley Ridge, as evidenced by the relatively high silt content.

These alluvial deposits provide groundwater for some irrigation wells in the areas surrounding Helena and West Helena, Arkansas. The irrigation wells are reportedly capable of producing approximately 1,000 gallons per minute (gpm). Groundwater flows generally toward the east to the Mississippi River.

The surface soil type at the site is the Convent Series, which consists of somewhat poorly drained, level soils that develop on alluvial fans at the foot of Crowley Ridge, a major regional structural feature. The Convent soils have medium-to-low organic matter content, moderate permeability, and high available water capacity.

Arkansas has a humid mesothermal climate characteristic of the southeast to south-central United States. The area rainfall is 50 inches per year, with most precipitation between February and April. Phillips County is an attainment area for all primary and secondary air pollutants. The prevailing wind is southwest at an average speed of 8 mph and travels in that direction 12.3% percent of the time. The average annual temperature is 62.7°F.

2.3.6.2 Potentially Exposed Populations

This section describes who may be exposed to contaminants in environmental media. For example, the potentially exposed populations for both current and future land use are site workers, site trespassers, and offsite residents. Future land use assumptions would be protective of current land use receptors, so exposure will be estimated for only future land use receptors. The Cedar Chemical site will likely be an agricultural chemical facility in the future, based on the current site structures and associated process equipment as well as its location in an industrial park.

As reported in the FI, nineteen residences down- or across-gradient from the West Helena facility were either visited or observed during the residential well survey. These residences are shown on Figure 2-4 in the FI. FI Table 2-2 identifies all residences visited during the

residential well survey. Wells formerly supplied all residences with domestic water; however, all homes have been connected to the city water system for more than 10 years. Based on the survey, the wells are currently in various states of disrepair: some are capped, some are open with no pumps, others have nonusable pumps. Several residences on Tappen Road, northwest of the site, were also surveyed; all those residences are connected to city water. Several upgradient wells on Old Little Rock Road were also visited; some of these residences still have old wells, but all residents are on city water. None of the residences surveyed is currently using private wells as a source of drinking water.

Several residences are located within a 1-mile radius of the site. These residences are primarily on Phillips Road.

2.3.6.3 Exposure Pathways

This section of the RA summarizes how potential receptors (site workers, trespassers, etc.) may be exposed to contaminated media. Soil matrix-related pathways include incidental ingestion, dermal contact, inhalation of volatile organic compounds (VOCs) volatilized from soil, and inhalation of fugitive dust.

For groundwater, ingestion and inhalation of volatilized contaminants will be the primary pathways of exposure evaluated. The Cedar Chemical plant receives water from two potable water supplies. The front offices, shower room, and laboratory receive potable water from the City of West Helena. The City of Helena supplies the rest of the plant.

Table 2-1 presents a preliminary list of exposure pathways which will tentatively be included in the RA. Table 2-1 also presents the rationale for selecting and excluding each exposure pathway. A similar table will be included in the RA.

Table 2-1
Preliminary Exposure Pathways Summary
Cedar Chemical Risk Assessment Work Plan
West Helena, Arkansas

Potentially Exposed Population	Medium and Exposure Pathway	Pathway Selected for Evaluation?	Reason for Selection or Exclusion
Current Land Uses			
Current/Future Site Workers	Air, Inhalation of gaseous contaminants emanating from soil	Yes	VOCs identified as COPCs in surface soil will be addressed for this exposure pathway, if applicable. Future land use assessment is considered to be protective of current receptors.
	Air, Inhalation of chemicals entrained in fugitive dust	Yes	Exposure to dust generated by site users traversing the area will be assessed in the RA. Future land use assessment is considered to be protective of current receptors.
	Surface Water, Ingestion of contaminants	No	Based on the chemical processes and site worker activities, this exposure pathway would not be completed for the industrial scenario.
	Surface Water, Inhalation of volatilized surface water contaminants	No	Based on the chemical processes and site worker activities, this exposure pathway would not be completed for the industrial scenario.
	Groundwater, Ingestion of contaminants during potable or general use	Yes	Shallow groundwater is not currently used as a source of potable or non-residential water.
	Groundwater, Inhalation of volatilized shallow groundwater contaminants	Yes	Shallow groundwater is not currently used as a source of potable or non-residential water.
	Soil, Incidental ingestion	Yes	This exposure pathway will be addressed based on site-specific worker traffic patterns.
	Soil, Dermal contact	Yes	This exposure pathway will be addressed based on site-specific worker traffic patterns.
	Sediment, Incidental ingestion	No	Based on the chemical processes and site worker activities, this exposure pathway would not be completed for the industrial scenario.

Table 2-1
Preliminary Exposure Pathways Summary
Cedar Chemical Risk Assessment Work Plan
West Helena, Arkansas

Potentially Exposed Population	Medium and Exposure Pathway	Pathway Selected for Evaluation?	Reason for Selection or Exclusion
	Sediment, Dermal contact	No	Based on the chemical processes and site worker activities, this exposure pathway would not be completed for the industrial scenario.
Future Land Uses			
Future Residents (Child and Adult)	Air, Inhalation of gaseous contaminants emanating from soil	Yes	VOCs identified as COPCs in surface soil will be addressed for this exposure pathway, if applicable.
	Air, Inhalation of chemicals entrained in fugitive dust	Yes	Exposure to dust generated by site users traversing the area will be assessed in the RA.
	Surface Water, Ingestion of surface water contaminants	No	This exposure pathway will be addressed for the site trespasser scenario only. The site trespasser scenario is approximately equivalent to a recreational scenario and would be protective of site residents.
	Surface Water, Inhalation of volatilized surface water contaminants	No	This exposure pathway will be addressed for the site trespasser scenario only. The site trespasser scenario is approximately equivalent to a recreational scenario and would be protective of site residents.
	Groundwater, Ingestion of contaminants during potable or general use	Yes	Data from shallow perched groundwater will be excluded from the RA.
	Groundwater, Inhalation of volatilized contaminants during domestic use	Yes	Data from shallow perched groundwater will be excluded from the RA.
	Soil, Incidental ingestion	Yes	Surface soil exposure pathways will be assessed.
	Soil, Dermal contact	Yes	Surface soil exposure pathways will be assessed.

Table 2-1
Preliminary Exposure Pathways Summary
Cedar Chemical Risk Assessment Work Plan
West Helena, Arkansas

Potentially Exposed Population	Medium and Exposure Pathway	Pathway Selected for Evaluation?	Reason for Selection or Exclusion
	Sediment, Incidental ingestion	No	This exposure pathway will be addressed for the site trespasser scenario only. The site trespasser scenario is approximately equivalent to a recreational scenario and would be protective of site residents.
	Sediment, Dermal contact	No	This exposure pathway will be addressed for the site trespasser scenario only. The site trespasser scenario is approximately equivalent to a recreational scenario and would be protective of site residents.
	Wild game or domestic animals, Ingestion of tissue impacted by media contamination	No	Chemicals reported in the FI would not be expected to accumulate and would be directly toxic to the organism, as opposed to chemicals typically considered to be bioaccumulators. In addition, irrigation via wide-area spray irrigation methods used in the area would strip many chemicals from groundwater. These issues will be evaluated further in the RA.
	Fruits and vegetables, Ingestion of plant tissues grown in media	No (Qualified)	Chemicals reported in the FI could accumulate in plants, but would be directly toxic to plants. In addition, irrigation via wide-area spray irrigation methods used in the area would strip many chemicals from groundwater These issues will be evaluated further in the RA.

Table 2-1
Preliminary Exposure Pathways Summary
Cedar Chemical Risk Assessment Work Plan
West Helena, Arkansas

Potentially Exposed Population	Medium and Exposure Pathway	Pathway Selected for Evaluation?	Reason for Selection or Exclusion
Future Site Trespassers (Adolescents, 7 through 16 years old)	Air, Inhalation of gaseous contaminants emanating from soil	Yes	VOCs identified as COPCs in surface soil will be addressed for this exposure pathway, if applicable.
	Air, Inhalation of chemicals entrained in fugitive dust	Yes	Exposure to dust generated by site users traversing the area will be assessed in the RA.
	Surface Water, Ingestion of surface water contaminants	Yes	Exposure to surface water will be assessed for this exposure pathway.
	Surface Water, Inhalation of volatilized surface water contaminants	Yes	Exposure to surface water will be assessed for this exposure pathway.
	Groundwater, Ingestion of contaminants during potable or general use	No	Groundwater is not used as drinking water, and this exposure pathway would not be completed for site trespassers.
	Groundwater, Inhalation of volatilized contaminants during domestic use	No	Groundwater is not used as drinking water, and this exposure pathway would not be completed for site trespassers.
	Soil, Incidental ingestion	Yes	Surface soil exposure pathways will be assessed.
	Soil, Dermal contact	Yes	Surface soil exposure pathways will be assessed.
	Sediment, Incidental ingestion	Yes	Sediment exposure will be assessed for site trespassers.
	Sediment, Dermal contact	Yes	Sediment exposure will be assessed for site trespassers.

2.3.6.4 Exposure Point Concentrations

The EPC is the concentration of a contaminant in an exposure medium that will be contacted by a real or hypothetical receptor. Determining the EPC depends on factors such as:

- Availability of data
- Amount of data available to perform statistical analysis
- Reference concentrations not attributed to site impacts
- Location of the potential receptor

USEPA guidance calls for assuming lognormal distributions for environmental data and calculating the 95th percentile UCL on the mean to quantify exposure. Applying the UCL is generally inappropriate with fewer than 10 samples. The maximum concentrations detected will be used as EPC for all datasets with less than 10 samples. In general, outliers have been included when calculating the UCL because high values seldom appear as outliers for a lognormal distribution. Including outliers increases the overall uncertainty of the calculated risks and conservatively increases the estimate exposure to a chemical.

For sample sets of 10 and greater, the UCL will be calculated in accordance with RAGS for a lognormal distribution as follows:

$$UCL = e^{\left(\bar{a}+0.5s_a^2 + \frac{H_{0.95}\ x\ s_a}{\sqrt{n-1}}\right)}$$

where:

$\bar{a}$	=	$\Sigma a/n$ = sample arithmetic mean of the log-transformed data, a = ln(x)
s_a	=	sample standard deviation of the log-transformed data
n	=	number of samples in the dataset
$H_{0.95}$	=	value for computing the one-sided upper 95% confidence limit on a lognormal mean from standard statistical tables (Gilbert, 1987)

The calculated values for the 95% UCL will be presented in tabular format (where applicable). The tables will statistically summarize COPCs identified in each environmental medium. The number of samples analyzed, mean and standard deviation of the natural log-transformed data (including the nondetect values), the H-statistic, the maximum of detected concentrations, and background concentrations (where available) will be included for each COPC.

Modified or alternate EPCs will be calculated for some chemicals because existing features or skewed contaminant distributions may be considered when estimating exposure. EPCs will be modified to account for the fraction of impacted areas covered with asphalt surface, buildings, and the like. Should existing features be maintained under the future industrial site use, direct exposure to affected areas (surface soil) would be effectively precluded. In some instances, factors will be derived to modify the EPC to account for the fraction ingested/contacted (FI/FC) from the contaminated source. This approach will be used where impacts are found to be extremely limited in areal extent (hot spots). Where this approach is taken, the basis for the decision will be discussed as is appropriate.

As previously discussed in the data management subsection (Section 2.3.3) of this document, analytical results will be presented as "nondetects" whenever chemical concentrations in samples do not exceed the detection or quantitation limits for the analytical procedures as applied to each sample. Generally, the quantitation limit is the lowest concentration of a chemical that can be reliably quantified above the normal, random noise of an analytical instrument or method. To apply the above-mentioned statistical procedures to a dataset with reported nondetects for organic compounds, the lesser of one-half of the nondetect value for the sample or the lowest *J*-qualified value at the site will be assumed to represent the applicable default concentration. For inorganic chemicals, one-half of the nondetect value will be assumed to represent the applicable concentration. Using this method is a reasonable compromise between use of zero and using the sample quantitation limit, to reduce the bias (positive or negative) in the calculated UCL.

2.3.6.5 Quantification of Exposure

This section describes the models, equations, and intake model variables used to quantify doses or intakes of the COPCs for the surface soil and groundwater exposure pathways. The methods which will be used are designed to estimate route- and medium-specific factors, which are multiplied by the EPC to estimate chronic daily doses. The intake model variables generally reflect 50th or 95th percentile values which, when applied to the EPC, ensure that the estimated intakes represent the reasonable maximum exposure (RME). Formulae were derived from RAGS, Part A unless otherwise indicated. Table 2-2 lists preliminary input parameters which will be used to compute chronic daily intake (CDI) for potential receptors exposed to surface soil and/or groundwater contaminants. These factors may be changed in the RA to reflect the most recent exposure information available, and any changes will be discussed. Age-adjusted ingestion factors were derived for the potential future residential receptors (resident adult and resident child combined) for carcinogenic endpoints. These factors consider the difference in daily ingestion rates for soil and drinking water, body weights, and exposure durations for children (ages 1 to 6) and adults (ages 7 to 31). The exposure frequency is assumed to be identical for the adult and child exposure groups.

Surface Soil Pathway Exposure

Ingestion of COPCs in Surface Soil

The following equation will be used to estimate the ingestion of COPCs in soil:

$$CDI_s = (C_s)(IR)(EF)(ED)(F)(FI)/(BW)(AT)$$

where:

CDI_s	=	ingested dose (mg/kg-day)
C_s	=	concentration of contaminant in soil (mg/kg)
IR	=	ingestion rate (mg/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
F	=	conversion factor (10^{-6} kg/mg)
FI	=	fraction ingested from contaminated source (unitless)
BW	=	body weight (kg)
AT	=	averaging time (days)

Table 2-2
Preliminary Exposure Parameters Used to Estimate CDI at RME

Pathway Parameters	Resident Adult	Resident Child	Adult Worker	Adolescent Trespasser	Units
Inhalation Rate	20[d]	12[d]	20[d]	20[d]	M^3/day
Ingestion Rate (soil)	100[a]	200[a]	50[a]	50[a]	mg/day
Ingestion Rate (water)	2	1	1	NA	L/day
Exposure Frequency	350[b]	350[b]	250[b]	52	days/year
Exposure Duration	24[c]	6[c]	25[c]	10	years
Dermal Contact Area	4,100[d]	2,900[d]	4,100[d]	4,100[d]	cm^2
Skin Adherence Factor	1	1	1	1	mg/cm^2
Absorbance Factor	0.01 (organics) 0.001 (inorganics)	0.01 (organics) 0.001 (inorganics)	0.01 (organics) 0.001 (inorganics)	0.01 (organics) 0.001 (inorganics)	unitless
Dermal Adjustment Factor	0.8 (VOCs) 0.5 (other organic compounds) 0.2 (inorganics)	0.8 (VOCs) 0.5 (other organic compounds) 0.2 (inorganics)	0.8 (VOCs) 0.5 (other organic compounds) 0.2 (inorganics)	0.8 (VOCs) 0.5 (other organic compounds) 0.2 (inorganics)	unitless
Conversion Factor	0.000001	0.000001	0.000001	0.000001	kg/mg
Body Weight	70[a]	15[a]	70[a]	45[a]	kg
Averaging Time, Noncancer [e]	8,760	2,190	9,125	3,650	days
Averaging Time, Cancer [f]	25,550	25,550	25,550	25,550	days

Notes:

a = USEPA (1989a) "Risk Assessment Guidance for Superfund Vol. I, Human Health Evaluation Manual (Part A)."

b = USEPA (1991b) "Risk Assessment Guidance for Superfund Vol. I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors," Interim Final, OSWER Directive: 9285.6-03.EPA/600/8-89/043.

c = USEPA (1991a), "Risk Assessment Guidance for Superfund: Vol. I — Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals)," OSWER Directive 9285.7-01B.

d = Resident Adult accounts for head, hands, and forearms at 90th percentile values from Table 4B.1, Exposure Factors Handbook; assumes individual is clothed with shoes, long pants, and short sleeves; rounded up from 4,090 cm^2.
Resident Child accounts for head, hands, forearms, lower leg, and feet using 90th percentile total body surface area values for male children 1 to 6 year olds (6,000 cm^2 assumed for 1 to 2 years old); because individual body part information is not available for 5 to 6 year olds, mean of other groups was assumed. Forearm surface area set equal to 46% of full arm; lower leg set equal to 41% of full leg measurement.

e = Calculated as the product of exposure duration (years) x 365 days/year.

f = Calculated as the product of 70 years (assumed lifetime) x 365 days per year.

NA = Not applicable.

Dermal Contact with COPCs in Surface Soil

The following equation will be used to estimate intake due to dermal contact with COPCs in soil:

$$CDI_{sd}=(C_s)(CF)(EF)(ED)(F)(FC)(ABS)(AF)/(BW)(AT)$$

where:

CDI_{sd}	=	dermal dose (mg/kg-day)
C_s	=	concentration of contaminant in soil (mg/kg)
CF	=	contact factor (cm^2)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
F	=	conversion factor (10^{-6} kg/mg)
FC	=	fraction contacted from contaminated source (unitless)
ABS	=	absorption factor (unitless value, specific to organic versus inorganic compounds)
AF	=	adherence factor (mg/cm^2)
BW	=	body weight (kg)
AT	=	averaging time (days)

Fugitive Dust Pathway Exposure

Inhalation of COPCs in Fugitive Dust

The following equation will be used to estimate the inhalation of COPCs in fugitive dust:

$$CDI_{dust}=(C_s)(IN)(PEF)(EF)(ED)(F)(FI)/(BW)(AT)$$

where:

CDI_{dust}	=	inhaled dose (mg/kg-day)
C_s	=	concentration of contaminant in soil (mg/kg)
IN	=	inhalation rate (M^3/day)
PEF	=	particulate emission factor (M^3/kg)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
F	=	conversion factor (10^{-6} kg/mg)
FI	=	fraction ingested from contaminated source (unitless)
BW	=	body weight (kg)
AT	=	averaging time (days)

Site-specific PEFs will be calculated in accordance with USEPA's Soil Screening Guidance (USEPA, 1994). If site data do not support a calculating a PEF, USEPA's default PEF of 6.79×10^8 will be used if warranted (USEPA, 1994).

Groundwater Pathway Exposure

Ingestion and Inhalation of COPCs in Groundwater

The following equation will be used to estimate the ingestion and/or inhalation of COPCs in groundwater:

$$CDI_w = (C_w)(IR)(EF)(ED)(FI)/(BW)(AT)$$

where:

CDI_w	=	ingested/inhaled dose (mg/kg-day)
C_w	=	concentration of contaminant in water (mg/L)
IR	=	ingestion rate (L/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
FI	=	fraction ingested from contaminated source (unitless)
BW	=	body weight (kg)
AT	=	averaging time (days)

Figures 2.1 and 2.2 provide the formulae for calculating the CDI for soil and groundwater, respectively. Tables will be used to present exposure to environmental media through all applicable pathways. Future site worker and hypothetical offsite resident exposure projections are provided separately. In accordance with USEPA guidance, the potential exposure to volatiles originating from groundwater during showering and domestic use has been estimated to be equivalent to that ingested through consumption of 2 liters/day of contaminated groundwater. Although the inhalation CDI computed on this basis is equal to that for ingestion exposures, risk and/or hazard associated with inhaled volatile contaminants are characterized using toxicological values specific to the inhalation pathway (e.g., inhalation slope factors [SFs] and reference doses [RfDs]).

2.3.7 Toxicity Assessment

2.3.2.1 Carcinogenicity and Noncancer Effects

The USEPA has established a classification system for rating the potential carcinogenicity of environmental contaminants based on the weight of scientific evidence. The cancer classes are described below. Cancer weight-of-evidence class "A" (human carcinogens) means that human toxicological data have shown a proven correlation between exposure and the onset of cancer (in varying forms). The "B1" classification indicates some human exposure studies have implicated the compound as a probable carcinogen. Weight-of-evidence class "B2" indicates a possible human carcinogen, a description based on positive laboratory animal data (for carcinogenicity) in the absence of human data. Weight-of-evidence class "C" identifies possible human carcinogens, and class "D" indicates a compound not classifiable for its carcinogenic potential. The USEPA has established SFs for carcinogenic compounds. The SF is defined as a "plausible upper-bound estimate of the probability of a response (cancer) per unit intake of a chemical over a lifetime" (RAGS, Part A).

In addition to potential carcinogenic effects, most substances can also produce other toxic responses at doses greater than experimentally derived threshold concentrations. The USEPA has derived RfD values for these substances. A chronic RfD is defined as *an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure concentration for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime.* These toxicological values are used in risk formulae to assess the upper-bound level of cancer risk and noncancer hazard associated with exposure to a given contaminant concentration.

Figure 2.1

Formulae for Calculating CDI for Soil

SOIL INHALATION OF FUGITIVE DUST PATHWAY

Residential Scenario:

Noncarcinogens - Child - Residential Scenario:

$$CDI_{NC\text{-}C} = \frac{C_s \times IR_{soil/child} \times PEF \times EF_{res} \times F \times FI \times ED_{child}}{AT_{NC\text{-}C} \times BW_{child}}$$

Noncarcinogens - Adult - Residential Scenario:

$$CDI_{NC\text{-}A} = \frac{C_s \times IR_{soil/adult} \times PEF \times EF_{res} \times F \times FI \times ED_{adult}}{AT_{NC\text{-}A} \times BW_{adult}}$$

Carcinogens (based on a lifetime weighted average):

$$CDI_C = \frac{C_s}{AT_C} \left[\frac{IN_{soil/child} \times PEF \times EF_{res} \times F \times FI \times ED_{child}}{BW_{child}} + \frac{IN_{soil/adult} \times PEF \times EF_{res} \times F \times FI \times ED_{adult}}{BW_{adult}} \right]$$

Figure 2.1 (continued)

SOIL INGESTION PATHWAY

Residential Scenario:

Noncarcinogens - Child - Residential Scenario:

$$CDI_{NC\text{-}C} = \frac{C_s \times IR_{soil/child} \times EF_{res} \times F \times FI \times ED_{child}}{AT_{NC\text{-}C} \times BW_{child}}$$

Noncarcinogens - Adult - Residential Scenario:

$$CDI_{NC\text{-}A} = \frac{C_s \times IR_{soil/adult} \times EF_{res} \times F \times FI \times ED_{adult}}{AT_{NC\text{-}A} \times BW_{adult}}$$

Carcinogens (based on a lifetime weighted average):

$$CDI_C = \frac{C_s}{AT_C} \left[\frac{IR_{soil/child} \times EF_{res} \times F \times FI \times ED_{child}}{BW_{child}} + \frac{IR_{soil/adult} \times EF_{res} \times F \times FI \times ED_{adult}}{BW_{adult}} \right]$$

Figure 2.1 (continued)

SOIL DERMAL CONTACT PATHWAY

Residential Scenario:

Noncarcinogens - Child - Residential Scenario:

$$CDI_{NC\text{-}C} = \frac{C_s \times CF_{soil/child} \times EF_{res} \times F \times FC \times AF \times ABS \times ADJ \times ED_{child}}{AT_{NC\text{-}C} \times BW_{child}}$$

Noncarcinogens - Adult - Residential Scenario:

$$CDI_{NC\text{-}A} = \frac{C_s \times CF_{soil/adult} \times EF_{res} \times F \times FC \times AF \times ABS \times ADJ \times ED_{adult}}{AT_{NC\text{-}A} \times BW_{adult}}$$

Carcinogens (based on a lifetime weighted average):

$$CDI_C = \frac{C_s}{AT_C} \times \left[\frac{CF_{soil/child} \times EF_{res} \times F \times FC \times AF \times ABS \times ADJ \times ED_{child}}{BW_{child}} + \frac{CF_{soil/adult} \times EF_{res} \times F \times FC \times AF \times ABS \times ADJ \times ED_{adult}}{BW_{adult}} \right]$$

Figure 2.1 (continued)

Formulae for Calculating CDI for Surface Soil

Variable	Description
BW_{child}	average child body weight (ages 1-6) (kg)
BW_{adult}	average adult body weight (kg)
ABS	absorbance factor (unitless value specific to organic versus inorganic compounds)
ADJ	dermal to absorbed dose adjustment factor (unitless value specific to VOCs, SVOCs, and inorganic compounds)
AF	adherence factor (1 mg/cm^2)
ED_{child}	child exposure duration during (ages 1-6) (yr)
ED_{adult}	adult exposure duration during (ages 7-31) (yr)
$ED_{adult-w}$	adult worker or trespasser exposure duration during (yr)
EF_{res}	residential exposure frequency (days/year)
EF_{w}	worker or trespasser exposure frequency (days/year)
$IN_{soil/child}$	child soil inhalation intake rate (M^3/day)
$IN_{soil/adult}$	adult soil inhalation intake rate (M^3/day)
$IR_{soil/child}$	child soil ingestion intake rate (mg/day)
$IR_{soil/adult}$	adult soil ingestion intake rate (mg/day)
PEF	particulate emission factor (M^3/kg)
FC	fraction contacted from contaminated source (unitless)
$CF_{soil/child}$	child soil dermal contact factor (mg/day)
$CF_{soil/adult}$	adult soil dermal contact factor (mg/day)
AT_{C}	averaging time (carcinogen)
AT_{NC-A}	averaging time (noncarcinogen adult)
AT_{NC-C}	averaging time (noncarcinogen child)
C_s	chemical concentration in surface soil (mg/kg)
FI	fraction ingested from contaminated source (unitless)
F	conversion factor (10^{-6} kg/mg)

Notes:

CDI indicates Chronic Daily Intake

The trespasser and worker scenario risk and hazard are calculated by substituting the corresponding assumptions into the adult portions of the formulae and then deleting the child portions of the formulae.

Figure 2.2

Formulae for Calculating CDI for Groundwater

GROUNDWATER INGESTION PATHWAY

Residential Scenario:

Noncarcinogens - Child - Residential Scenario:

$$CDI_{NC\text{-}C} = \frac{C_w \times IR_{water/child} \times EF_{res} \times ED_{child} \times FI}{AT_{NC\text{-}C} \times BW_{child}}$$

Noncarcinogens - Adult - Residential Scenario:

$$CDI_{NC\text{-}A} = \frac{C_w \times IR_{water/adult} \times EF_{res} \times ED_{adult} \times FI}{AT_{NC\text{-}A} \times BW_{adult}}$$

Carcinogens (based on a lifetime weighted average):

$$CDI_C = \frac{C_w}{AT_C} \left[\frac{IR_{water/child} \times EF_{res} \times ED_{child} \times FI}{BW_{child}} + \frac{IR_{water/adult} \times EF_{res} \times ED_{adult} \times FI}{BW_{adult}} \right]$$

Figure 2.2 (continued)

Formulae for Calculating CDI for Groundwater

PATHWAY: GROUNDWATER INHALATION WHILE SHOWERING

Residential Scenario:

In accordance with Technical Memorandum Guidance on Estimating Exposure to VOCs During Showering. USEPA/ORD, July 10, 1991:

$$CDI_{ingestion} = CDI_{inhalation}$$

Variable	Description
BW_{child}	average child body weight (ages 1-6) (kg)
BW_{adult}	average adult body weight (kg)
ED_{child}	child exposure duration during (ages 1-6) (yr)
ED_{adult}	adult exposure duration during (ages 7-31) (yr)
$ED_{adult\text{-}w}$	adult worker exposure duration during (yr)
EF_{res}	residential exposure frequency (days/year)
EF_{w}	worker exposure frequency (days/year)
$IR_{water/child}$	child water intake rate (mg/day)
$IR_{water/adult}$	adult water intake rate (mg/day)
FI	fraction ingested from contaminated source (unitless)
AT_{C}	averaging time (carcinogen)
$AT_{NC\text{-}A}$	averaging time (noncarcinogen adult)
$AT_{NC\text{-}C}$	averaging time (noncarcinogen child)
C_{w}	chemical concentration in groundwater (mg/L)

Notes:

CDI indicates Chronic Daily Intake

The worker scenario risk and hazard are calculated by substituting worker-specific assumptions into the adult portions of the formulae and then deleting the child portions of the formulae.

For carcinogens, the potential risk posed by a chemical is computed by multiplying the CDI (as mg/kg-day) by the SF (in reciprocal mg/kg-day). The HQ (for noncarcinogens) is computed by dividing the CDI by the RfD. The USEPA has set standard limits (or points of departure) for carcinogens and noncarcinogens to evaluate whether significant risk is posed by a chemical (or combination of chemicals). For carcinogens, the point-of-departure range is 10^{-6}, with a generally accepted range of 10^{-6} to 10^{-4}. These risk values correlate with a 1 in 10,000 and a 1 in 1,000,000 excess incidence of cancer resulting from exposure to xenobiotics (all pathways).

For noncarcinogens, other toxic effects are generally considered possible if the HQ (or sum of HQs for a pathway, HI) exceeds 1.0. Although both cancer risk and noncancer hazard are generally additive (within each group) only if the target organ is common to multiple chemicals, a most conservative estimate of each may be obtained by summing the individual risks or hazards, regardless of target organ. HI will be calculated in the RA by summing the individual risks or hazards, regardless of target organ. More details regarding target organs and mechanisms of action will be incorporated into the RA as is appropriate. Additional details regarding the risk formulae applied to site data are provided in Section 2.3.8, Risk Characterization, of this document.

Critical studies used in establishing toxicity classifications by USEPA are shown in the IRIS database (primary source) and/or HEAST, Fiscal Year 1995 (secondary source). If toxicological information is unavailable in IRIS or HEAST, values will be obtained from reports issued by the Environmental Criteria and Assessment Office (ECAO)/National Center for Environmental Assessment (NCEA). Where applicable, these values will also be included in the database for the RA. In accordance with RAGS, the RA will include a table summarizing toxicological data in the form of RfDs and SFs obtained for the relevant COPCs, as well as uncertainty/modifying factors, target organs, and cancer classes (where available).

2.3.2.2 Toxicity Profiles for COPCs

In accordance with RAGS, the RA will include brief toxicological profiles for all COPCs. Most information for the profiles will be obtained from IRIS and HEAST or alternate sources, as mentioned in the preceding text. Any additional references will be noted specifically in the profiles. The profiles will summarize adverse effects of COPCs and the amounts associated with such effects.

2.3.8 Risk Characterization

Risk characterization combines the results of the exposure assessment and toxicity assessment to yield qualitative and quantitative expressions of risk and/or hazard for the exposed receptors. The quantitative component expresses the probability of developing cancer, or a nonprobabalistic comparison of the estimated dose with a reference dose for noncancer effects. These quantitative estimates will be developed for individual chemicals, exposure pathways, transfer media, and source media, and for each receptor for all media to which a receptor may be exposed. The qualitative component usually involves comparing COC concentrations in media with established criteria or standards for chemicals for which there are no corresponding toxicity values. The risk characterization is used to guide risk management decisions.

Generally, the risk characterization will follow the methodology prescribed by RAGS Part A, as modified by more recent information and supplemental USEPA guidance cited earlier. The USEPA methods are designed to be health-protective, and tend to overestimate, rather than underestimate, risk. The risk results, therefore, are generally overly conservative, because risk characterization involves multiplying the conservative assumptions built into the exposure and toxicity assessments.

This section of the RA will characterize the potential health risks associated with the intake of chemicals originating from the site. The USEPA methods used to estimate the types and magnitudes of health effects associated with exposure to chemicals will be supplemented, where

appropriate, by graphical representations of risk and hazard. The objective of presenting this supplemental information is to more clearly depict the problem areas and associated sampling media.

Risk Characterization Methodology

Risks to humans following exposure to COPCs will be estimated using methods established by USEPA, when available. These health-protective methods are likely to overestimate risk. Risks from hazardous chemicals are calculated for either carcinogenic or noncarcinogenic effects. Some carcinogenic chemicals may also pose a noncarcinogenic hazard. The potential human health effects associated with chemicals that produce systemic toxic and carcinogenic influences are characterized for both types of health effects. As mentioned in Section 2.3.6.5, inhalation exposure-related risk and hazard will be computed using appropriate route-specific (inhalation) SFs and RfDs (where available).

Unlike the methods for estimating inhaled or ingested dose of COPCs, which quantify the dose presented to the barrier membranes (the pulmonary or gastrointestinal mucosa, respectively), dermal dose is estimated as the dose that crosses the skin and is systemically absorbed. For this reason, oral toxicity values must be adjusted to reflect the dermally absorbed dose.

Dermal RfD values and SFs are derived from the corresponding oral values. In deriving a dermal RfD, the oral RfD is multiplied by an oral absorption factor (ABF), expressed as a decimal fraction. The resulting dermal RfD is based on the absorbed dose, the appropriate value with which to compare a dermal dose, because dermal doses are expressed as absorbed rather than administered (intake) doses. For the same reasons, a dermal SF is derived by dividing the oral SF by the ABF. The oral SF is divided rather than multiplied because SFs are expressed as reciprocal doses.

Appendix A of RAGS, Part A, states that in the absence of specific data, an assumption of 5% oral absorption efficiency would be relatively conservative. Supplemental Guidance to RAGS: Region IV Bulletin indicates that in the absence of specific data, USEPA Region IV suggests an oral to dermal absorption factor of 80% for VOCs, 50% for SVOCs and 20% for inorganics. These percentages (or associated fractions) will be used in the RA and are reflected in the applicable risk/hazard results. Chemical-specific absorption factors will be used, if available.

Carcinogenic Effects of Chemicals

The risk attributed to exposure to carcinogens is estimated as the probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen. The following equations show the method which will be used to estimate cancer risk. In the low-dose range, which would be expected for most environmental exposures, cancer risk is estimated from the following linear equation (RAGS, Part A):

$$ILCR = (CDI)(SF)$$

where:

ILCR	=	incremental lifetime excess cancer risk, a unitless expression of the probability of developing cancer, adjusted for reference incidence
CDI	=	chronic daily intake, averaged over 70 years (mg/kg-day)
SF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$

For a given pathway with simultaneous exposure of a receptor to several carcinogens, the following equation is used to sum cancer risks:

$$Risk_p = ILCR(chem_1) + ILCR(chem_2) + \ldots ILCR(chem_i)$$

where:

$Risk_p$ = total pathway risk of cancer incidence

$ILCR(chem_i)$ = incremental lifetime excess cancer risk for a specific chemical

Cancer risk for a given receptor across pathways and across media is summed in the same manner.

Noncarcinogenic Effects of Chemicals

The risks associated with the noncarcinogenic effects of chemicals are evaluated by comparing an exposure level or intake with a reference dose, and this method will be used to estimate noncancer risk or hazard. The HQ is defined as the ratio of intake to RfD is defined as (RAGS, Part A);

$$HQ = CDI/RfD$$

where:

HQ = hazard quotient (unitless)

CDI = intake of chemical (mg/kg-day)

RfD = reference dose (mg/kg-day)

Chemical noncarcinogenic effects will be evaluated on a chronic basis, using chronic RFD values. An HQ of unity or 1 indicates that the estimated intake equals the RfD. If the HQ is greater than unity, there may be a concern for potential adverse health effects.

For simultaneous exposure of a receptor to several chemicals, an HI will be calculated as the sum of the HQs by:

$$HI = HQ_1 + HQ_2 + \ldots HQ_i$$

where:

HI = Hazard Index (unitless)

HQ = Hazard Quotient (unitless)

Risk and hazard projections will be summarized in tabular format for each medium following the general discussions of risk and hazard quantification methods.

2.3.8.1 Surface Soil Pathways

This section of the RA summarizes estimated surface soil risk/hazard for each receptor group. In addition, the primary contributors to carcinogenic risk and/or noncarcinogenic hazard are discussed.

2.3.8.2 Groundwater Pathways

This section of the RA summarizes estimated groundwater risk/hazard for each receptor group. In addition, the primary contributors to carcinogenic risk and/or noncarcinogenic hazard are discussed.

2.3.8.3 Other Applicable Pathways

This section of the RA summarizes estimated risk/hazard for each receptor group and discusses the primary contributors to carcinogenic risk and/or noncarcinogenic hazard for any additional exposure pathways included in the RA.

2.3.8.4 Identification of COCs

This section summarizes the outcome of risk/hazard projections by identifying COCs for each impacted environmental medium. COCs will be identified for each medium based on cumulative (all pathway) risk and hazard projected for each site, and will be shown in tabular form (where necessary). USEPA has established a generally acceptable risk range of 10^{-4} to 10^{-6}, and an HI threshold of 1.0 (unity). In accordance with RAGS, a COC will be considered to be any

chemical contributing to a cumulative risk level of 10^{-4} or greater and/or a cumulative HI above 1.0, and whose individual ILCR exceeds 10^{-6} or whose HQ exceeds 0.1. A table will be used to summarize COCs identified that will also note exposure pathways of concern.

2.3.8.5 Risk/Hazard Maps

In addition to the standard tabular presentation of risk/hazard, summary risk and hazard contour maps may be provided (where appropriate) for applicable environmental media to provide a visual supplement. When they are used in an FI, point-location maps are generally developed to show the distribution and concentration of individual chemicals or groups of chemicals, or the risk/hazard associated with potential exposure through applicable pathways.

As an extension of conventional risk/hazard determinations, risk and hazard will be calculated based on each COC's concentration at each sample location. Point-location maps will be constructed for each medium and pathway for which sufficient data are available. Maps and other graphics will be prepared only when they are considered a useful aid in data interpretation and/or decision-making. Narratives will be provided where graphical presentations are inappropriate or unsupported with site data. If COCs are not identified in the RA for a medium, risk maps will not be developed for that medium.

Surfer for Windows and other standard graphical data presentation and geographic information system packages, will be used to plot the risk/hazard projections on site maps. The maps will illustrate risk or hazard associated with COCs in the subject medium. The risk/hazard for individual locations will be based exclusively on chemicals detected. For groundwater (where applicable), maps will be provided addressing analytical results from the most recent sampling event. These results will be supplemented as necessary with data collected at various times and from temporary wells. If the quarterly groundwater data are supplemented or data from temporary wells are used, it will be discussed in the RA. Tables summarizing the data used to generate graphical presentations will also be presented. This information allows the reviewer

to determine the nature of the contaminants identified, the primary contributors to risk and hazard at each sample location, and also facilitates remedial alternatives screening.

2.3.9 Risk Uncertainty

This section of the RA presents and discusses the uncertainty and/or variability inherent in the risk assessment process in addition to medium-specific and exposure pathway-specific influences. Understanding the uncertainty and variability inherent in the risk assessment process as well as site-specific sources of uncertainty and variability are key to making informed risk management decisions. RA sections will be discussed separately in the uncertainty section, and specific examples of uncertainty sources will be included where appropriate.

Where chronic RME estimates of risk/hazard indicate that a significant threat would be posed to human health, Central Tendency (CT) analyses will be performed. CT exposure scenarios will be constructed consistent with standard CT exposure assumptions provided in *Superfund's Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure-Draft* (USEPA, November 1993). CT risk estimates will be presented in the uncertainty section of the RA, and presentation will be similar to that in the risk characterization section.

2.3.10 Risk Summary

Risk and hazard projected for each receptor group, exposure medium, and exposure pathway will be summarized in this section.

2.3.11 Remedial Goal Options

RGOs are chemical concentrations computed to equate with specific risk and/or hazard goals that may be established for a particular site. As previously discussed, COCs are identified as any COPC that significantly contributes to a pathway of concern. A pathway having an ILCR greater than 10^{-4} or an HI greater than 1 is defined as a pathway of concern, and an individual

chemical which contributes either 10^{-6} ILCR or 0.1 HI is considered to significantly contribute to the pathway ILCR or HI. RGOs will be calculated for all COCs identified. These are listed in the Risk Characterization section of the RA. Inclusion in the RGO table does not necessarily indicate that remedial action will be required to address a specific chemical. Instead, RGOs will be provided to facilitate risk management decisions.

In accordance with USEPA Supplemental RGO Guidance, RGOs will be calculated at 10^{-4}, 10^{-5}, and 10^{-6} risk levels for carcinogenic COCs and HQ goals of 3, 1, and 0.1 for noncarcinogenic COCs. RGOs will be calculated for specific receptors and exposure pathways to provide one concentration per receptor per medium, which will be noted on the each of the corresponding tables.

3.0 REFERENCES

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